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(54) Method and device for multienergy scanning

(57) An X-ray device and method that can be used to generate digital images in which the use of passive selection devices that utilize the principle of diffraction and/or reflection makes it possible to select a part of the spectrum emitted by a radiogenic tube and thus transmit an X-ray beam characterized by a restricted energy band.

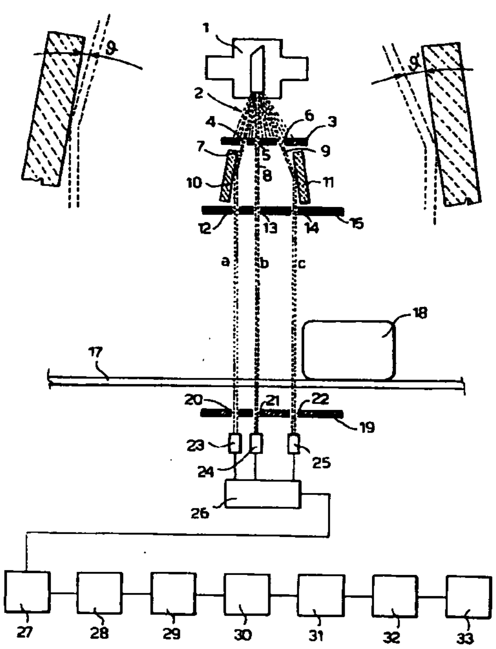

FIG.1

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Description

[0001] The present invention relates to a device and a method for multienergy scanning, based on the production and detection of X rays, to form images and detect differences in the materials of the object examined.

[0002] The invention is particularly suitable in the security field for inspection of both hand and hold luggage, postal parcels or cargo. Moreover, it can be used in the medical-scientific field to examine a biological entity, be it a person or an animal; in the ecological field to examine refuse or used containers, in the food sector, when the object to be examined consists of packaged or unpackaged foodstuffs.

[0003] So-called multienergy scanning systems are devices based on the production and detection of X rays which, besides being able to provide a black and white image in which each pixel of the digital image obtained has a gray value which is a function of the radiolucency of the object targeted, provide an image, generally in false colours, in which the pixel value expresses a certain classification of the composition of the materials x-rayed. The algorithms employed on these systems to distinguish such substances are based on processing of the data entered, which include at least a pair of register images of the same object each of which is made by reading the radiation incident on the detection system having a different spectral quality of the X-rays. The difference in the spectral quality is evaluated quantitatively after the radiation has interacted with the target and then from the results of this estimate the aforementioned algorithms move to determine the composition of the materials through with the radiation passes which, normally but not necessarily, can be expressed in terms of mean atomic number.

[0004] The quality of the register images is critical not only for the purposes of an appreciable and informative display for an operator who must evaluate the nature of said image, recognizing, for example, the presence of objects or artefacts to which attention must be paid, but also as regards the use of the algorithms that must extract the information on the composition of the materials.

[0005] There are various devices and methods that can be implemented in commercially available products, with the object of providing X-ray images capable of recording differences in the materials so as to be able to generate what is defined as a multispectral signal.

[0006] For example, U.S. patent 4.626.688 discloses the use of a detection system based on a double array of solid state detectors placed one on top of the other which are in register and are separated by a filter of special material. In said configuration the filter attenuates the lower-energy components of the incident spectrum, differentiating the readings of the double array of detectors. In this way the array of detectors situated upstream of the filter reads the low-energy component of the spectrum and the array of detectors situated downstream of the filter reads the high-energy component of the spectrum.

[0007] Other types of devices use a square-wave or pulse train electrical voltage feed source for the radiogenic tube, which oscillates synchronously, with respect to the readings of a single array of detectors, between two different voltages. In this way, alternate readings, at different times of the detection system, make it possible to read signals having a different spectral quality even at the origin, that is before interaction with the target. A high-energy spectrum is read by the detection synchonized with the high-voltage pulse, and a low-energy spectrum is read by the detection synchronized with the low-voltage impulse.

[0008] GB 2 287 164 describes a configuration that uses a system, such as a conveyor belt for example, that enables the object to be examined, commonly called the target, to be moved linearly, and two pairs of spatially separated detection/source systems, in which the two sources, consisting of radiogenic tubes, are fed at different voltages. In said configuration the two arrays of detectors at different times read a radiation that passes through the same region of the target produced with a different emission spectrum at the origin. The array of detectors corresponding to the source fed at high voltage will read the high-energy spectrum, whilst the row of detectors corresponding to the source fed at low voltage will read the low-energy spectrum.

[0009] FR 2 705 791 describes a configuration that uses a type of detector intrinsically capable of discriminating the content of the incident radiation in energy. The single detector is made of a single silicon crystal with various layers; since high-energy photons penetrate silicon to a greater extent that low-energy photons, the spectrum composition of the object explored with the rays is reconstructed from the readings performed in the various layers of the detector.

[0010] All the above described known techniques have drawbacks in that the problem of the strong energy correlation of the images acquired with such systems remains unsolved. Said correlation, which is translated into poor image quality, especially when the aim is to extract information on the composition of materials is basically due to the overlapping at the origin of the spectra used to produce images at different energies.

[0011] Even in the configurations in which two different peak voltages are utilized to feed the radiogenic tube (as in the second and third example above), the two spectra obtained, although differently modulated in amplitude, are still largely overlapping, that is, they contain significant amplitudes on the same common range of energies. Consequently, in the signal reconstruction stage, the amount of information on the composition of the targeted material proves poor.

[0012] The object of the invention is to eliminate said drawbacks providing a device and a method capable of enhancing the quality of the images, so as to be able to draw adequate conclusions on the composition of the materials.

[0013] This object is achieved in accordance with the invention, with the characteristics listed in the appended independent claims.

[0014] Preferred embodiments of the invention emerge from the dependent claims.

[0015] In the device and method according to the invention, the intrinsic correlation between the spectra of the signals is minimized. In fact, different images are created by making incident on the same target X-ray beams obtained by selecting appropriately restricted energy bands of the emission spectrum of a beam coming from a radiogenic tube.

[0016] In this manner the X-ray beams incident on the target not only are of different quality, but also, to all effects, by interacting on the material to be inspected, they test its radio-opacity characteristics at different energies that are well separated from each other.

[0017] Consequently, the spectra of the signals detected have little correlation, therefore during the signal reconstruction stage the amount of information on the composition of the material being examined is considerably greater than in the various cases illustrated with the prior art.

[0018] The device according to the invention substantially comprise:

- an X-ray source, such as, typically, a radiogenic tube;
- at least one device placed between the ray source and the object to be examined, able to select, exploiting the principle of diffraction and/or reflection of X-rays, wavelengths among those contained in the emission spectrum of said source within a restricted energy band;
- means able to detect the X-ray signal and then form images of an object, such as, for example, solid state detectors or ionization chambers;
- computer devices able to control the system and the image acquisition process and to support the software used to perform the classification of the materials, as well as any other algorithm necessary to perform the specific application.

[0019] Further characteristics of the invention will be made clearer by the detailed description that follows, referring to a purely exemplary and therefore non-limiting embodiment thereof, illustrated in the appended drawings, in which:

Figure 1 is a general diagram of the device according to the invention;
Figure 2 is a diagram of the three spectra relating to the three beams *a, b, c* in Figure 1, incident on the detectors.

[0020] A device according to the invention is described with reference to Figure 1.

[0021] An X-ray source, preferably a radiogenic tube 1, emits a polychromatic X ray beam 2 or any beam of rays produced within a voltage range of 140-150 kV.

[0022] The polychromatic beam 2 is mad to pass through a first primary collimator 3 which has three through cavities 4, 5 and 6 from which three polychromatic beams 7, 8 and 9, respectively, can emerge. The X-ray beam 7 is directed on a first crystal monochromator 10. Crystals monochromators are mosaic crystal structures having such a crystal lattice as to obtain Bragg's diffraction of the incident X-ray beam.

[0023] Bragg's relation is given by the formula:

$$\sin\theta = \frac{k.\lambda}{2.a} \qquad (1)$$

[0024] Where θ is the angle of incidence of the X-ray beam, λ is the wavelength of the X-ray beam, *a* is the pitch of the crystal monochromator lattice and k = (1,2,3, ...) is an integer number that represents the order of diffraction. The electromagnetic waves of the X-ray bean, are summed constructively in the direction given by Bragg's relation (1) and destructively in all other directions.

[0025] If the crystal monochromator 10 is inclined so as to form an angle of incidence θ, with respect to the incident beam 7, according to the formula (1), an almost monochromatic, high-energy diffracted beam with a restricted band, denoted by letter *a* in the figure, is obtained.

[0026] The beam 9 is incident on a second crystal monochromator 11, with an inclination θ' different from (greater than) the inclination θ between the beam 7 and the crystal 10.

[0027] The angle of incidence θ' is selected so as to obtain a monochromatic low-energy beam *c*.

[0028] The beams *a*, 8, *c* are made to pass respectively through 3 through cavities 12,13,14 made in a second pri-

mary collimator 15. Emergent from the cavity 12 is the high-energy monochromatic beam *a*; emergent from the cavity 13 is a polychromatic high-energy beam *b*; emergent from the cavity 14 is the monochromatic low-energy beam c.

[0029] Said three beams *a,b,c* are incident on a conveyor belt 17 on which an object for inspection 18 advances.

[0030] Beneath the conveyor belt 17 is positioned a secondary collimator 19, in which there are three through cavities 20, 21, 22 destined respectively to allow the beams *a, b, c* to pass.

[0031] Beneath the cavity 20 is situated a first array of solid state detectors 23, able to detect the high-energy radiation coming from the monochromatic beam *a*.

[0032] Beneath the cavity 22 is positioned a second array of solid state detectors 25 able to detect the radiation coming from the low-energy monochromatic beam *c*.

[0033] Beneath the cavity 21 is positioned a third array of solid state detectors 24, able to detect the radiation coming from the high-energy polychromatic beam *b*.

[0034] The output from the arrays of detectors 23, 24, 25 is transmitted, in a substantially known manner, to a multiplex 26 which selects a voltage signal to transmit to an integrator 27 which can consist of an operational amplifier configured as an integrator.

[0035] The signal emergent from the integrator 27 is transmitted to a sampling circuit 28 which can consist of a sample and hold circuit.

[0036] The analog signal sampled is passed through an image correcting unit 29 which makes a correction to the gain variations due to the preceding stages. The signal emerging from the image corrector 29 is transmitted to an anolog-to-digital converter 30 which translates the analog signal into a digital signal, then the digital signal is stored in a memory 31. The signal resident in the memory 31 is picked up by a video output circuit 32 where the images to be sent to a monitor 33 are reconstructed.

[0037] This monitor 33 has a phosphor video or a liquid crystal display capable of showing the user the image of the object 18 inspected.

[0038] Computer devices are provided that are able to control the system as a whole and the image acquisition process, and to support the software used to carry out classification of the materials, as well as any other algorithm needed to perform the specific application.

[0039] Figure 2 shows the spectra incident on the arrays of detectors 23, 24, 25 coinciding respectively with beams *a, b, c,* which have passed through an object 18 to be inspected with a thickness equivalent to 1 cm of iron.

[0040] The spectrum for beam *a* is shown with a dashed line, the spectrum for beam *b* with a solid line and the spectrum for beam *c* with a dotted line.

[0041] In the example shown the primary polychromatic beam *b* is produced at the voltage of 140 kV, the crystal monochromator 10 is oriented so that it selects a diffracted monochromatic beam *a* with a mean energy of 120 kV and the crystal monochromator 11 is oriented so that it selects a diffracted monochromatic beam *c* with a mean energy of 70 keV.

[0042] From Figure 2 it is clear that the spectrum relating to beam *a* and the spectrum relating to beam *c* have an entirely negligible spectral overlap. The correlation therefore being minimum, several items of information concerning the composition of the material inspected can be obtained from the reconstruction and processing of the signal.

[0043] It is clear therefore that the invention fully achieves the established objects.

[0044] Of the three beams *a,b,c,* just two are normally sufficient to obtain the desired information.

[0045] In place of the crystals monochromators 10, 11, equivalent means suitable for determining a diffraction or a reflection of the beam of X rays, to obtain beams with a restricted energy band, can be used.

[0046] Likewise, in place of the solid state detectors 23, 24, 25 ionization chambers or equivalent means can be used.

[0047] In practice, the invention is not limited to the particular embodiment previously described and illustrated in the appended drawings, but is open to numerous modifications to the details, without thereby departing from the scope of the invention itself, as defined by the claims that follow.

Claims

1. A multienergy scanning device for forming X-ray images and detecting differences in the materials making up an object (18), comprising:

   at least one X-ray source;
   collimator means able to direct at least two X-ray beams on the object (18),
   means for detecting the X-rays passing through the object, and
   means for processing the signals of said detectors to form the image of the object,
   characterized in that between said X-ray source and the object to be examined (18) is interposed at least one selector means, able to select, exploiting the principle of diffraction and/or reflection of X rays, wavelengths among those contained in the emission spectrum of said source within a restricted energy band, to generate

at least one of said at least two X-ray beams.

2. A device according to claim 1, in which said at least one X-ray source comprises a radiogenic tube (1).

3. A device according to claim 1, in which one of said at least two X-ray beams directed on the object (18) comes directly from said source (1), and the other from said selector means.

4. A device according to claim 1, in which at least two beams of X rays directed on the object (18) come from as many selector means.

5. A device according to claim 1, in which at least two beams of X rays directed on the object (18) are formed by means of a single selector means.

6. A device according to claim 5, characterized in that means are provided to set said source (1) in motion, and/or means to set said selector means in motion and/or to set in motion said means for detecting the rays passing through the object.

7. A device according to any one of the preceding claims, characterized in that said selector means comprise at least one crystal monochromator (10, 11).

8. A device according to claim 7, characterized in that said crystal monochromators (10, 11) are oriented with respect to said X-ray source (1) according to the energy of the beam to be selected.

9. A device according to claim 1, characterized in that said means for detecting the X rays passing through the object comprise at least one linear array of solid-state detectors (23, 24, 25).

10. A device according to claim 1, in which said means of detecting the X rays passing through the object comprise ionization chambers.

11. A device according to any one of the preceding claims, characterized in that the spatial location of said X-ray detectors is correlated to the mean energy of the X-ray beam.

12. A device according to any one of the preceding claims, characterized in that said object (18) advances on a conveyor belt (17).

13. A multienergy scanning method for forming X-ray images and detecting differences in the materials making up an object (18), consisting in irradiating said object (18) with at least two beams of X-rays, at least one of which is a restricted energy band obtained by selecting, through diffraction and/or reflection, wavelengths among those contained in the emission spectrum of an X-ray source, the rays passing through the object to be examined being intercepted by detector means and processed to form the image of the object.

14. A method according to claim 13, characterized in that it provides for the formation of a plurality of beams with a restricted energy band, so that the images acquired of the object to be examined are associated with progressively increasing or decreasing mean energy values of the beam, such as to achieve a sampling of the absorption properties of the material at different energies.

15. A method according to claim 13 or 14, characterized in that said beams with a restricted energy band are generated by means of the movement of the X-ray source and/or the movement of the diffraction and/or reflection means, and/or the movement of the means for detecting the X rays passing through the object.

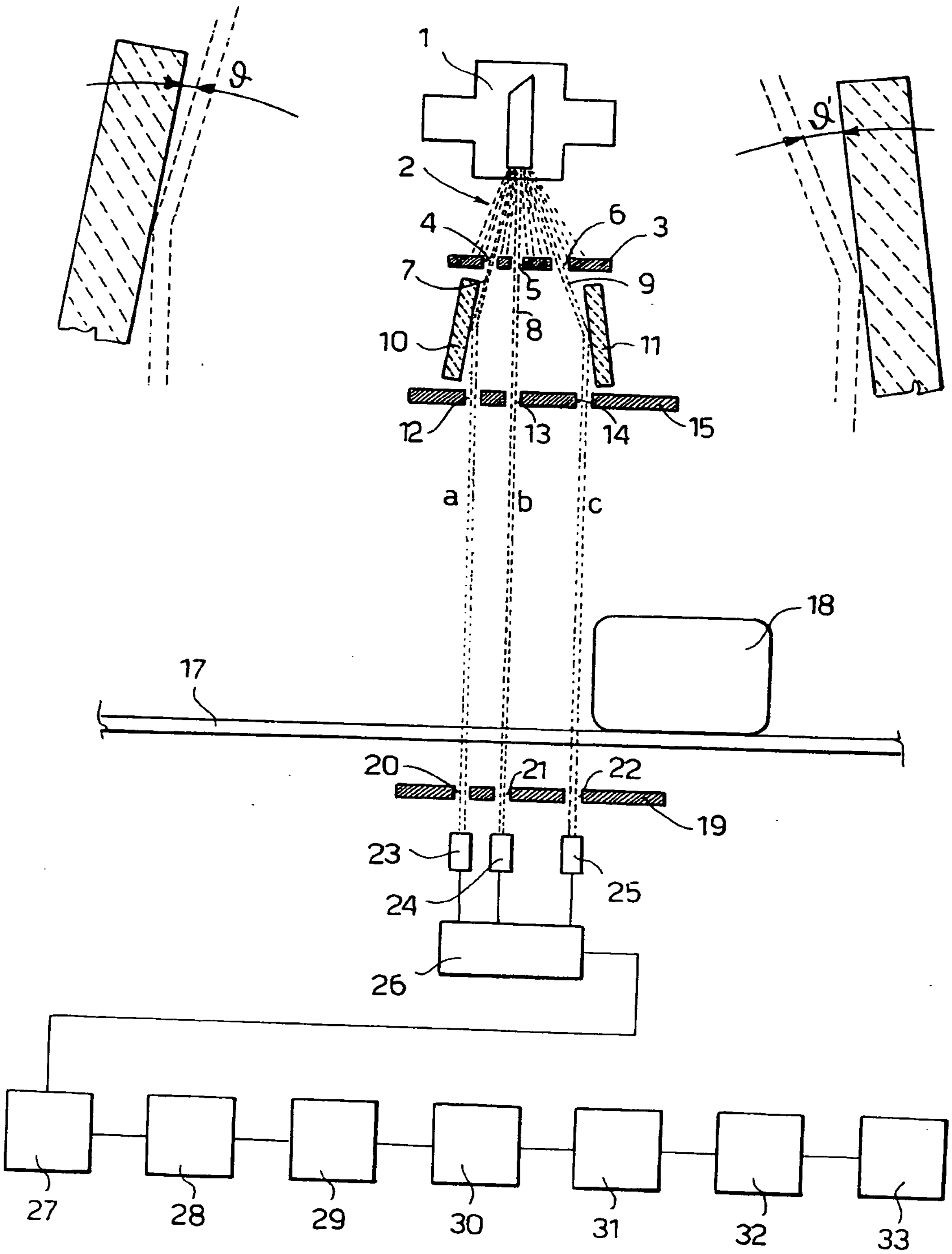
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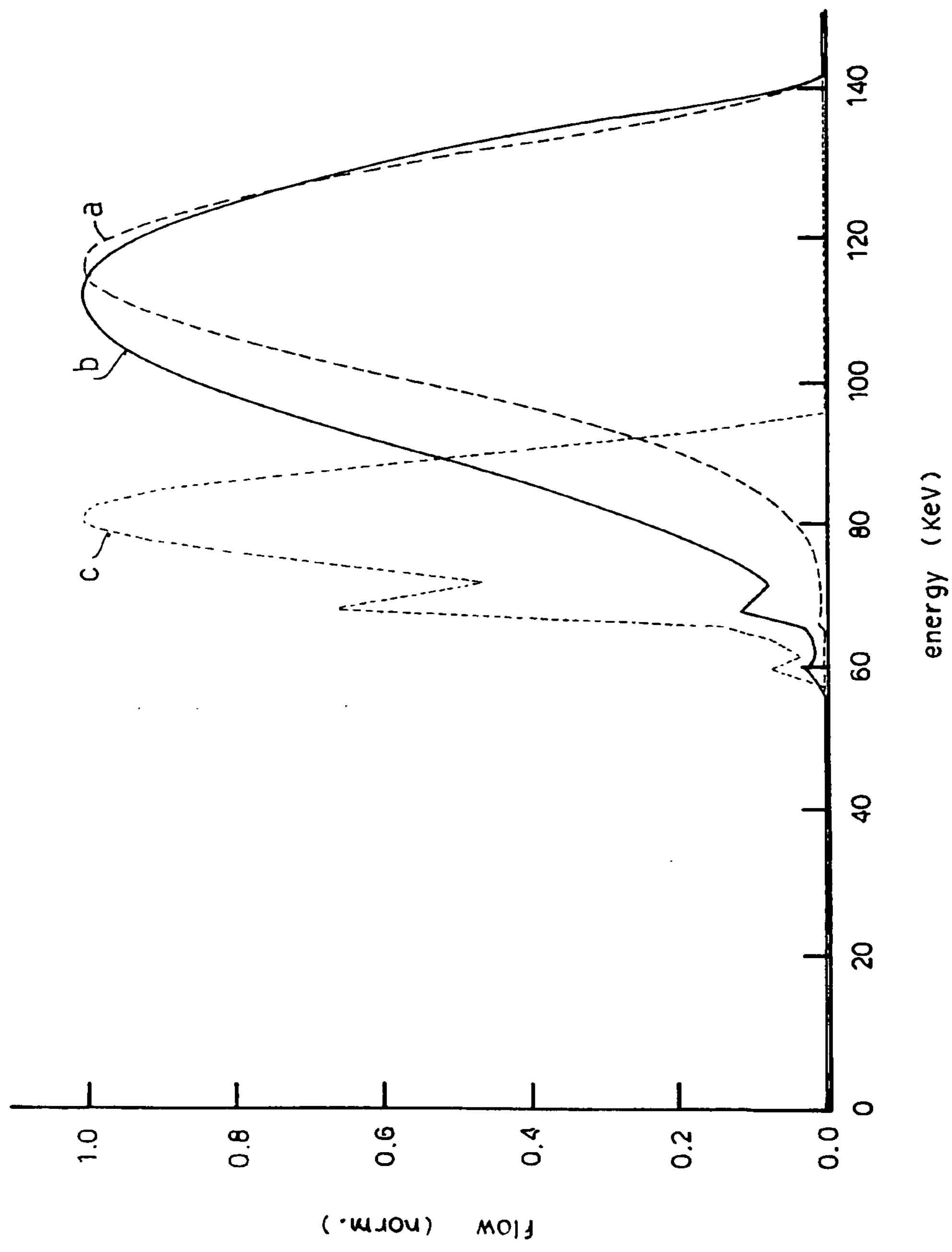
FIG.1



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a
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FIG. 2